

**United States Patent Application for:**

**A MAGNETIC MEMORY STORAGE DEVICE  
AND METHOD FOR READING AND WRITING**

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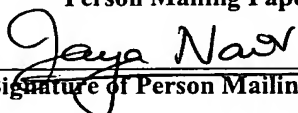
**Attorney Docket No. CMI-001**

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2 [0001] **A MAGNETIC MEMORY DEVICE AND METHOD**  
3 **FOR MAGNETIC READING AND WRITING**

4 [0002] **CROSS REFERENCE TO RELATED APPLICATION**

5 This application claims the benefit of U.S. provisional application serial no.  
6 60/471,801, filed May 20, 2003 which is fully incorporated by reference.

7  
8 [0003] **Field of the Invention:**

9 [0004] The present invention pertains generally to memory storage devices and  
10 particularly to magnetic memory storage devices.

11  
12 [0005] **BACKGROUND OF THE INVENTION**

13  
14 [0006] Within the field of memories, there is continuing interest in finding ways  
15 to increase the storage density and speed. As the personal use of small devices gain  
16 popularity, the memory of these equipments has to be modified to match the function and  
17 design of these small devices. Particularly, as more and more data needs to be stored in  
18 the memory, the memory needs to have the capacity and speed to handle such demand.

19 [0007] The discovery of new phenomena of magnetoresistive (MR) and  
20 giantmagnetoresistive (GMR) effect provided a significant advancement in the field of  
21 memory technology. This phenomena demonstrated that resistance of multilayer thin  
22 film comprised of ferromagnetic layers sandwiching a conducting layer can change  
23 significantly depending on the direction of an external magnetic field.

24 [0008] GMR is observed in magnetic metallic layered structures in which it  
25 is possible to orient the magnetic moments of the ferromagnetic layers relative to one  
26 another. One such type magnetic metallic layered structure consists of a stack of four  
27 magnetic thin films: a free magnetic layer, a nonmagnetic conducting layer, a magnetic  
28 pinned layer and an exchange layer. Magnetic orientation of the pinned layer is fixed  
29 and held in place by the exchange layer. By applying an external magnetic field, the  
30 magnetic orientation of the free layer may be changed with respect to the magnetic  
31 orientation of the pinned layer. The change in the magnetic orientation generates a  
32 significant change in the resistance of the metallic layered structures. The resistance of

1 the structure determines the logical value to be stored therein.

2 [0009] Currently this technology is predominantly used in the disk drives. Disk  
3 drives use discs which are coated with a magnetizable medium for storage of digital  
4 information in a plurality of concentric data tracks. A track is a concentric set of  
5 magnetic bits on the disk. A sector is a part of each track that is defined with a magnetic  
6 marking and an ID number. A cylinder is group of tracks with the same radius. In a  
7 typical magnetic disk drive, a magnetic disk rotates at high speed and a read-write head  
8 uses air pressure to “fly” over the top surface of the disk. The head records information  
9 on the surface of the disk by impressing a magnetic field on the disk. Information is read  
10 back using the head by detecting magnetization of the disk surface. To access the disk  
11 requires a sequence of steps. The total time required to complete such sequence of steps  
12 is generally known as the access time. Access time has two major components: seek  
13 time and rotational latency. Seek time is the time needed for the read-write head to move  
14 radially to the cylinder containing the desired sector. Rotational latency is the additional  
15 time waiting for the disk to rotate the desired sector to the disk head. The access time is  
16 a sum of the seek time and the rotational latency time. The disk drives available today  
17 has an access time of 14 ms and this is too long for the future demand. The speed of the  
18 disk drive is negatively impacted by such long access time.

19 [0010] Spindle motors are generally used to rotate the disk at high speeds. A  
20 read-write head carried by a head slider is positioned over a track on the surface of the  
21 disk to write data to or read data from the track. The head slider is supported by a  
22 movable actuator which is controlled to position the read-write head carried by the head  
23 slider to a location with respect to the disk while the disk is rotating. However this  
24 arrangement using spindle motors are known to have problems. Even minor vibrations  
25 or bumps can cause the disk drive to crash. Mechanical constraints are limiting the  
26 function of the disk drive. Moreover, as the disk drives are being produced with  
27 increasing track densities and decreasing access time, the feedback control systems in  
28 modern disc drives must move the sliders to the correct position in a very short period of  
29 time. Seek errors may occur if the slider is not moved to the correct position.

30 [0011] As can be seen there is a clear need in the industry to have disk drives  
31 with shorter access time and without the mechanical constraints.

32 [0012] Meanwhile, a magnetic memory device known as Magnetoresistive  
33 Random Access Memory (MRAM) has been developed on an Integrated Circuit ( IC)

1 chip. This type of memory device generally includes conductive lines positioned  
2 perpendicular to one another. Each conductive lines act as either write or a bit line. A  
3 magnetic stack is placed where the two conductive lines cross. An electrical current  
4 flowing through one of the conductive line induces a magnetic field around that  
5 conductive line. A different current flowing through the other conductive line induces  
6 another magnetic field around the second conductive line. The induced magnetic fields  
7 align or realign the magnetic dipoles in the magnetic stack. The resistance of the  
8 magnetic stack determines the logical value to be stored therein.

9 [0013] For the MRAM the transistor logic circuits are embedded in the IC chip  
10 itself. As a result of having transistor logic circuit in close proximity with the  
11 magnetic stack, the magnetic field interferes with the functions of the logic circuit. The  
12 magnetic field interference with the control circuits also makes it difficult to integrate  
13 MRAM various devices. Moreover, the amount of memory available through the use of  
14 an MRAM is only in the range of 1Mbit. This amount of memory is not suitable for  
15 most applications. Also, since the MRAM is basically an IC chip it is not adaptable to  
16 other types of fabrications especially into memory devices like a disk drive.

17 [0014] While MRAMs provide a non-volatile memory it is not suitable for most  
18 of the present day applications due to its small amount of memory and inability to  
19 integrate, small amount of memory.

20 [0015] As can be seen there is clear need in the industry to have a memory device  
21 that is fast with a large memory and is durable.

22 [0016] **SUMMARY OF THE INVENTION**

23 It is accordingly an object of the invention to provide a memory storage device  
24 that overcomes the above mentioned disadvantages of the prior art devices of this general  
25 type.

26 [0017] One aspect of the invention includes a magnetic memory storage device  
27 having a read disk and a storage disk. The read disk includes of an array of read heads.  
28 The storage disk comprises of an array of magnetic storage elements. The magnetic  
29 storage elements are disposed between a plurality of conducting lines. The individual  
30 read head on the disk has a corresponding storage element on the storage disk.

31 [0018] The individual read head includes two layers. The first layer includes a  
32 pinned layer and a first free layer. The magnetic field of the pinned layer fixed. The

1 magnetic field orientation of the free layer may vary depending on other variables.

2 [0019] The writing operation involves passing current through the conducting  
3 lines on the storage disk. The current through conducting lines will induce a magnetic  
4 field around the storage element. The storage element includes a second free layer. The  
5 direction of magnetization of second free layer may vary. Accordingly, the induced  
6 magnetic field fixes the direction of the magnetization of the second free layer. The  
7 direction of magnetization of the second free layer determines the value to be stored.

8 [0020] The reading and writing operation in the memory storage device is  
9 performed and controlled by different circuits. For reading, a control circuit selects a  
10 read head from the array of read heads on the read disk to perform the reading. The  
11 second free layer of the corresponding storage element in the storage disk controls the  
12 direction of the magnetization of the first free layer. The resistance value of the read  
13 head depends on the magnetic direction of the pinned layer and the free layer. As the  
14 direction of the first free layer is controlled by the second free layer of the storage  
15 element, the direction of the first free layer depends on the stored value of the storage  
16 element. By measuring the resistance of the read head the stored value may be  
17 determined.

18 [0021] These and other objects, features, and advantages of the present invention  
19 will become more apparent upon reading the following detailed description in  
20 conjunction with the accompanying drawings.

21 [0022] **BRIEF DESCRIPTION OF THE DRAWINGS**

22 [0023] Figure 1 is a schematic top view of a storage disk 100.

23 [0024] Figure 2 is schematic bottom view of a read disk 200.

24 [0025] Figure 3a is a schematic top view of storage cell 300.

25 [0026] Figure 3b is a schematic cross sectional view of a storage cell 300 shown  
26 in Figure 3a.

27 [0027] Figure 4 shows a cross sectional view of structure 400 having read head  
28 402 and storage disk 406.

29 [0028] Figure 5a shows a cross sectional view of a read head 500.

30 [0029] Figure 5b shows a cross sectional view of a storage element 403.

31 [0030] Figure 5c shows a cross sectional view of a storage cell unit 520 having a

1 read disk and a storage element.

2 [0031] DETAILED DESCRIPTION OF THE DRAWINGS

3 [0032] FIG. 1 shows a schematic top views of a storage disk 100. The storage  
4 disk 100 comprises of a plurality of conducting lines 102. Disposed between the  
5 conducting lines are an array magnetic storage elements 104. A control circuit (not  
6 shown) will select a particular storage element from the array of magnetic storage  
7 elements. A current through the conducting lines will induce a magnetic field and it  
8 magnetizes the selected storage element. The magnetic storage elements have a single  
9 axis of magnetization. The direction of the magnetization is fixed by the induced  
10 magnetic field and the direction of magnetization is interpreted as a binary 1 or 0.

11 [0033] Each of the magnetic storage element is capable of storing at least one bit  
12 of data. Each magnetic storage element 104 is exchangeably isolated from other storage  
13 elements in the array. However the storage elements 104 are strongly exchange coupled  
14 within the array of storage elements that enable them to function as a large single  
15 magnetic unit. It is understood that the magnetic storage elements shown in figure 1 are  
16 not drawn to scale. Each magnetic storage element are essentially the same size and has  
17 a single magnetic domain.

18 [0034] FIG. 2 is a schematic bottom view of a read disk 200. The read disk 200  
19 comprises of an array of read heads 204. Even this figure is not drawn to scale. Each  
20 one of the read heads on the read disk correspond to a storage element on the storage  
21 disk. The resistance of the read head depends on the direction of the magnetization of  
22 the corresponding storage element on the storage disk in FIG. 1. The resistance of the  
23 read head 200 determines the logical value to be stored therein.

24 [0035] The reading and writing process in this embodiment of the invention is  
25 accomplished by two different circuits. Writing is done by the storage disk and its  
26 controlling circuits and reading is done by the read head and its controlling circuits. The  
27 read heads may be an MR, GMR, or CMR. Separating the circuits to accomplish reading  
28 and writing provides a lot more control over the circuit. Also, by having corresponding  
29 heads for each storage element the seek and latency time associated with the disk drives  
30 are virtually eliminated. It is understood that even though here we are showing a one to  
31 one mapping between the storage elements and the read heads that is not a necessity.

1 Several storage elements may be mapped to a single read head.

2 [0036] It should be appreciated that the current design avoids the need for  
3 mechanical components like spindle motor and servo. As a result, this memory storage  
4 device is not limited by the mechanical capabilities. Another unique feature of the  
5 invention is that the disks are not required to spin at high speeds thus providing reliability  
6 and making it immune from crashes. Also, this design is more durable as the present  
7 embodiment virtually eliminates the dependence on mechanical components in turn it is  
8 less susceptible to damage from shock or vibration.

9 [0037] The present invention keeps the control circuits to select the desired  
10 storage element during write operation and the read head during read operation are  
11 external to the read disk and the storage disk. This allows the active circuit elements to  
12 be kept away from the magnetic material and this will prevent leakage and bit to bit  
13 interference.

14 [0038] Figure 3a is top view of an individual storage cell 300 on a storage disk  
15 (not shown) similar to the one shown in Figure 1. The cell 300 includes conductive lines  
16 302. A magnetic storage element 304 disposed between the conductive lines. A current  
17 through the conductive lines will induce a magnetic field around the storage element.  
18 This in turn will magnetize the storage element. The magnetic storage element has a  
19 single axis of magnetization. The direction of the magnetization is interpreted as a  
20 binary 1 or 0. Figure 3b is the cross sectional view of the storage cell 300 shown in  
21 Figure 3a. Figure 3b shows the conductive lines 302 and magnetic storage element 304  
22 disposed between the conductive lines.

23 [0039] Figure 4 shows a cross sectional view of a magnetic storage device 400.  
24 The device include a read disk 402 and a storage disk 406. The read disk has read heads  
25 404. The storage disk 406 has magnetic storage elements 408 disposed between  
26 conductive lines (not shown). A current through the conductive lines (not shown) will  
27 induce a magnetic field. This in turn will magnetize the storage element. The  
28 magnetic storage element 408 has a single axis of magnetization. The direction of the  
29 magnetization is interpreted as a binary 1 or 0. Depending on the value stored in the  
30 storage element i.e. 1 or 0 the resistance of the read head 304 is changed. Reading is  
31 done by measuring the resistance of the read head.

32 [0040] Figure 5a shows a cross sectional view of a read head 500. The read head  
33 includes a pinned layer 502 and a first free layer 504. The direction of the magnetization

1 in the pinned layer 502 is fixed. The direction of the magnetization of the first free layer  
2 504 may vary. Figure 5b shows a cross sectional view of a storage element 503. The  
3 storage element has a second free layer 506. The direction of the magnetization of the  
4 second free layer controls the direction of magnetization of the first free layer 504 in the  
5 read head 500. Figure 5c shows a magnetic unit cell 520 in the magnetic storage device  
6 (not shown). The magnetic unit cell 520 includes read head 500 of Figure 5a and a  
7 storage element 503 of Figure 5b. The read head 500 and the storage element 503 are  
8 separated by an optional conductive layer 508 on the read head. The conductive layer  
9 508 acts as a router to make connection with the control circuit. It is fabricated from  
10 paramagnetic material such as tantalum. The pinned layer 502 and the first free layer 504  
11 of the read head 500 makes up the MR, GMR or the CMR.

12 [0041] The method of writing is done by passing current through conductive lines  
13 (not shown) surrounding the storage element 503 which induces a magnetic field. The  
14 induced magnetic field magnetizes the second free layer 506 of the storage element 503.  
15 The direction of the magnetization of the second free layer depends on the logical value  
16 to be written. The second free layer 506 and the first free layer 504 are magnetically  
17 coupled thus the direction of the magnetization of the second free layer 506 determines  
18 the direction of magnetization in the first free layer 504. If the direction of the  
19 magnetization of the first free layer 504 and the pinned layer 502 are in the same  
20 direction the resistance will be low. If the direction of the magnetization of the  
21 magnetization of the first free layer 504 and the pinned layer 502 are in the opposite  
22 direction the resistance would be high. Accordingly if the resistance is low the value  
23 read will be 1 and if the resistance is high the value read will be a logical zero. The  
24 method of reading is done by measuring the resistance of the first free layer 504 and the  
25 pinned layer 502.

26 [0042] Even though the description shows a read disk and a storage disk, it is  
27 understood that the devices need not circular like a disk. It can take any shape as it is not  
28 an integrated circuit (IC) chip. This can be adapted into other types of devices such as a  
29 cell phone, personal digital assistant (PDA), video games, MP3s etc. It can be used for  
30 mass storage of digital data. The memory of the storage device described herein varies  
31 from mega bit to the giga bit range depending on application. The memory storage  
32 device can be integrated virtually into any device because the active circuit elements are  
33 separated from the magnetic elements. Since the memory storage device is not an IC



1 chip it can be made to fit the shape of the device into which it would be incorporated  
2 into.

3 [0043] Additional advantages include higher amount of current through the  
4 conducting lines as the area used for storage may range from 1 square centimeter to  
5 several hundred square centimeter. Also the number of conducting lines, around the  
6 storage element, through which the desired current would pass, to magnetize the free  
7 layer, in the storage element, may be adjusted according to the amount of current needed  
8 for magnetization.

9 [0044] While embodiments of the invention have been illustrated and described,  
10 it is not intended that these embodiments illustrate and describe all possible forms of the  
11 invention. Rather, the words used in the specification rather than limitation, and it is  
12 understood that various changes may be made without departing from the spirit and  
13 scope of the invention.